526.9
W
46

Levelling Operations

Mb

No. 6762

DEPARTMENT OF

5269 W46

LIBRARY OF

Illinois Industrial University,

CHAMPAIGN, ILLINOIS.

BOOKS ARE NOT TO BE TAKEN FROM THE LIBRARY ROOM.

REMOTE STORAGE

UNIVERSITY OF
LIBRARY
ILLINOIS.

HINTS

ON

LEVELLING OPERATIONS

AS APPLIED TO THE

READING OF DISTANCES BY THE LAW OF PERSPECTIVE,
AND THE SAVING THEREBY OF CHAINMEN IN A LEVEL SURVEY.

WITH

REMARKS ON THE OTHER ADVANTAGES THAT CAN BE GAINED
IN A SURVEY BY ADOPTING THIS PRINCIPLE IN THE USE OF ANY
ORDINARY LEVELLING TELESCOPE AND STAFF.

ILLINOIS INDUSTRIAL UNIVERSITY LIBRARY
6762

BY

W. H. WELLS, C.E.,

BENGAL PUBLIC WORKS DEPARTMENT.

UNIVERSITY OF ILLINOIS LIBRARY

LONDON:
E. & F. N. SPON, 46, CHARING CROSS.
NEW YORK:
446, BROOME STREET.

1879.

526.9
W
46

a. c.
s. c. Levelling.

PREFACE.

ALTHOUGH the method of reading distances by the law of perspective, whereby the apparent size of an object diminishes as its distance from the eye of the observer, has been applied in range-finding telescopes, and also to some extent in levelling and surveying telescopes, as in Gravatt's level, and Edgeworth's stadiometer, its usefulness in levelling operations appears to have been very little recognized as yet by surveyors, as the measurement of the distances in levelling operations by the chain is still almost universal, as far as I am aware, and all surveying books as a rule teach that the distances between the level heights on a survey line must be measured by the surveyor's chainman.

I have been induced to publish the following short treatise, as I believe that very many surveyors and engineers are either unaware of the use to which the common unalterable law of perspective can be put in levelling operations, or have, at all events, failed to realize how manual labour, to say nothing of the inaccuracy of careless chainmen, can be saved by utilizing this principle in reading distances, and I did not myself, until lately, realize its advantages, which, I believe, will be much more generally utilized in future levelling instruments.

I have endeavoured to show in this treatise—

First. How the chain can be altogether dispensed with

in a level survey, and the distances from the level to the several heights taken be read off the staff at the same time as those level heights are read; and how this can be done without in the least altering the existing level or staff, which any surveyor has been accustomed to use. See Part I.

Secondly. How this can be still more effectually and quickly done by adding a simple contrivance, which can be attached to any existing instrument by the surveyor himself, and which also enables the breadth of large rivers and similar obstacles on or off the survey line to be read without measurement. See Parts II., III., and IV.

I have also added in Part V. a description of the method of keeping a level book in three columns only, for the information of those unacquainted with that method, as it is a convenient and concise form of level book, especially if the distances are read, as explained in Part I.

The method adopted in Gravatt's level for reading the distances by fixed cross hairs, besides not allowing so much use of the law of perspective to be taken advantage of in reading distances, as a movable point in the diaphragm allows, is open to the objection, that if the hairs get out of adjustment or otherwise injured, the surveyor cannot readjust them himself, whereas he can check and readjust the vertical space in the diaphragm, as often as he likes, to the datum he is using, if he attaches to his level a contrivance with a movable point in the diaphragm of his instrument, as proposed in this treatise.

In this paper the term " vertical space " has been used to denote any space in the diaphragm of the telescope enclosed by two horizontal lines, or else between two points lying within or parallel to the vertical axis of the telescope, and a " vertical space " in the diaphragm will thus always enclose a certain portion of the image of an upright staff or other objects seen through the telescope.

To find the datum distance reading required by the surveyor to work out his distances, as explained in Part I. of this paper, he has only to measure 100 feet accurately, set his staff at that distance from his instrument, and read the portion of its image contained within the "vertical space" in the diaphragm.

If he uses the contrivance proposed in Part IV. of this paper, he has simply to set up his staff at 100 feet distance from his instrument, and with the thumb-screw of the contrivance adjust the "vertical space" in the diaphragm, until it exactly includes 1 foot of the staff image, and he then has his datum to proceed on with his survey, which he can check as often as he pleases.

Digitized by the Internet Archive
in 2017 with funding from
University of Illinois Urbana-Champaign Alternates

https://archive.org/details/hintsonlevelling00well

HINTS ON LEVELLING OPERATIONS

AS APPLIED TO THE

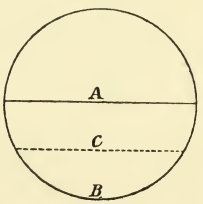
READING OF DISTANCES BY THE LAWS OF PERSPECTIVE.

PART I.

On the principle of using any ordinary levelling telescope and surveying staff, without any addition or alteration to them, in reading distances.

ACCORDING to the laws of perspective the size of the staff image or portion thereof seen in the telescope will diminish as the distance of the staff from the telescope increases, and, therefore, if the staff is placed, say, 100 feet distance from the telescope, and if at that distance 1·80 feet, for example, is the portion of the image of the staff contained within the space in the diaphragm of the telescope (Fig. 1), bounded by the horizontal cross hair or line (A) and the lower edge of the diaphragm (B), we have a datum whereby any distance that the staff is moved to can be determined from the portion of its image enclosed within the vertical space A B. (For finding datum, also see Preface.) For instance, if the staff is moved and the telescope directed on it, and the portion of the staff image contained within the space A B found to be 3·20 we have the simple proportion sum ∴ 1·80 : 3·20 :: 100 feet = 177·77 = distance to the staff.

FIG. 1.

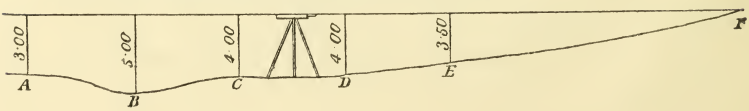


The surveyor has therefore only to settle his own datum distance at 100 feet, or otherwise, read the portion of the staff image enclosed within his diaphragm, or a portion thereof (as A B), and having noted this in his survey book, he can proceed with his levelling operations without a chain or other measuring apparatus; all he has to do is, when he reads the level height on the staff through his levelling telescope after adjustment, to read also the portion of the staff image contained within his diaphragm, or portion thereof determined on by him to be used as the vertical space to contain the "distance" figures. This in Fig. 1 is A B. It is better to use a second horizontal cross hair or line, as shown dotted at C, instead of the lower edge of the circular diaphragm, as giving a more accurate outline, and this can be done by fixing a hair horizontally near the bottom or top of the diaphragm. The distances will have to be worked out by a series of simple proportion sums when the level book is made up after the day's operations, and will be entered in the book as per following example or other convenient form:—

DATUM DISTANCE READING, say 1·80 of the staff image = 100 feet.

	Distance Readings.			Level Readings.			
	Back.	Fore.	Distance in feet worked out.	Back.	Inter-mediate.	Fore.	Reduced Levels.
A	3·20	..	177·7	3·00	—	—	—
B	1·80	..	100	..	5·00	—	—
C	1·00	..	55·5	..	4·00	—	—
D	—	1·00	55·5	..	4·00	—	—
E	—	3·20	177·7	..	3·50	—	—
F	—	5·00	277·7	..	..	0·00	—

Remarks.—In working out the distances for plotting purposes, a line is drawn between distances at C and D to show position of the instrument, as all distances are read back and fore from it. A line is also drawn under the foresight, where the instrument is moved.



The distances are worked out by a series of simple proportion sums between each distance reading and the *datum* distance reading. For instance, $\therefore 1{\cdot}80 : 3{\cdot}20 :: 100 = 177{\cdot}7$ = distance of A from instrument. The distances entered in the level book will of course be those between the position of the levelling instrument and the different staff positions back and fore of the instrument, and will be plotted accordingly. As the distances read are the horizontal ones, it will be seen that, more especially over rough and intricate ground, "read" distances will be more accurate than measured chain distances, besides saving labour and delay in chaining, and the anxiety often caused to the surveyor by careless chainmen. In all cases it will, I believe, be found as accurate as chain measurement, and even in cases where the surveyor still thinks it advisable to use the chain in the usual manner, the reading of the distance, as heretofore explained, is a check on those measured distances, and thus in any case of great service; and over difficult ground, or where woods have to be cut through to run the chain, or rivers crossed by the survey line, the extra benefit of reading the distances off the staff image will be evident to every practical surveyor. Thus, in running a line of levels a surveyor only requires his staffholder, and can, in most cases, dispense with his chainmen altogether. It will also be evident that areas of land can be taken in this manner with the ordinary level and staff, without measurement, if desired.

PART II.

On the more convenient and extended use of the principle, where the diaphragms of levelling instruments are slightly ALTERED OR ADDED TO, *as proposed herein.*

THE above-described method of reading distances through the medium of the portion of the staff image enclosed within any *convenient* vertical space bounded by hori-

zontal lines (such as A C in Fig. 1), in the diaphragm of levelling telescopes, is open to the objection that it is necessary to work out each distance by a simple proportion sum when the level book is made up after the day's work. If, however, that "vertical space" is exactly formed to take 1 foot of the staff image at 100 feet distance, it is evident that with such a datum no proportional sum is necessary to find the distances, but they can be read off the staff image at once, and noted in the level book. For instance, if the portion of the staff image enclosed within such space when the staff is moved beyond 100 feet is found to be 1·75 feet it will show that the distance is 175 feet. If the portion of the staff image enclosed is found to be 0·50 feet the distance would be 50 feet, and so on. Such is the application of the principle I am advocating in Edgeworth's stadiometer and Gravatt's level, alluded to in my Preface, and the vertical space is formed by two spider lines placed horizontally at such distance apart, that when the telescope is placed exactly 100 feet from the staff, the portion of its image enclosed between the lines is exactly 1 foot.

Such adjusted vertical space can only be applied to new instruments, or to the diaphragms of existing instruments, by an instrument maker; and by a diaphragm specially arranged for the purpose, and I now propose to show why it is advisable that the diaphragms should not be so arranged with a fixed vertical space, as in Edgeworth's stadiometer, but that an arrangement attached to the diaphragm should be given, whereby the vertical space can be regulated in depth by the surveyor himself by means of a thumb-screw, either below or above the diaphragm of the telescope. The advantages of such an arrangement are—

1st. That the surveyor can use either one, two, or more whole feet of the staff image as the datum for 100 feet distance, by diminishing or increasing the vertical space, and

the larger the datum space he determines to work with, the greater is the accuracy of the readings.

2nd. In the event of the surveyor wishing to read the distance to the other side of a river or other broad obstruction in his survey line, which distance is *beyond* the limits of vision at which the staff figures can be read, he can still read the distance across the river by the following method:—

The staff is placed on the opposite side of the river or other obstruction, and the vertical space in the diaphragm of the telescope is adjusted by the thumb-screw until either the whole staff or a portion of it, *the length of which in feet is known,* is exactly enclosed within the vertical space in the diaphragm. A second staff is then held at 100 feet from the telescope on the surveyor's side of the river, and the telescope, with the "vertical space" *unaltered,* is directed on this staff, and its figuring in feet enclosed within the vertical space is noted. The surveyor then has a proportional sum to give him the breadth of the river without measurement, which could otherwise only be found by the much more tedious but usual methods known to surveyors. For instance, if the "vertical space" in the diaphragm is adjusted to include the whole staff of 14 feet on the opposite bank, and the portion of the second staff enclosed within the same vertical space in the diaphragm at 100 feet distance from the instrument is found to be 1·20 feet, the distance to the opposite side of the river would be as 1·20 : 14·00 :: 100 feet = 1166·6 feet. The advantage of reading the distance of a broad river or other similar obstruction on the survey line, which would be tedious to determine by the chain, or without a theodolite, at the time of running a line of levels, is apparent.

PART III.

On the advantage of having a scale of equal parts adjacent to the mechanical arrangement for adjusting the vertical space in the diaphragm of the telescope, so arranged that its depth will be shown by a certain number of these equal parts on the scale.

For instance, if the "vertical space" is made adjustable in depth by a thumb-screw arrangement, as proposed in Part II. of this paper, and a scale of equal parts is fixed outside the telescope, so that a point conveniently attached to the adjusting arrangement will move along that scale as the vertical space is decreased or increased by the screw, it is evident that the depth of the "vertical space" will be shown by so many parts of that scale. The distance to any object on the other side of a river or otherwise can then be determined without a staff at all in the following manner. The telescope is directed on any object to which the distance is required, such as a tree or other convenient object, and the vertical space in the diaphragm adjusted until the object is exactly enclosed therein, and the number of equal parts on the scale, counting from zero (when the vertical space in the diaphragm is closed) until the object is exactly contained within the vertical space, is then noted. The telescope, or levelling instrument, is then moved backwards for a certain distance, say 100 feet or more, according to circumstances, and the same operation repeated, viz. adjusting the vertical space in the diaphragm until the object is exactly within it. It will then be seen from the scale of equal parts, that a smaller number of these parts represent the vertical space enclosing the object, owing to its distance being increased, and the distance from the first position of the observer to the object is found by the following proportion sum, ∴ number of equal parts of scale at first observation – number of equal parts of scale at second observation : number of equal parts of scale at first observation : : the distance that the telescope

was moved = distance required. For instance, if at the first point of observation 10 equal parts were noted as the depth of the vertical space enclosing the object, and at the second point of observation, 100 feet back from the first point of observation, 9 parts were noted. We have the proportion sum, $\therefore 10-9 : 10 :: 100 :$ distance required $= 1000$ feet. The use of the above method of range finding seems more serviceable for military and other operations, where it is necessary to determine long distances, than for surveying operations; but I have alluded to it here, as it appears to me that if the surveyor has determined to have the diaphragm of his levelling telescope adapted to reading distances by an adjustable "vertical space" therein, he may as well have a scale of equal parts added thereto, since there may be many cases in his surveying operations when he may wish to read the approximate distance to any object far away, either on or off his survey line.

While on the subject of long-range finding, I have to observe that as far as I am acquainted with the newest instruments for the purpose, the above method of applying the principle of perspective by altering the distance of observation has not been sufficiently recognized. One of the latest telescopes for range finding on the principle of perspective, was shown me a short time ago at Messrs. Elliot's, Strand, London. It has a very neat arrangement attached to the telescope, whereby two cross hairs in the diaphragm are decreased or increased in their distance apart, and the scale is arranged so that when a man's height, which is fixed at a certain average at any visible distance, is enclosed exactly within the hair lines, the distance to the man is given on the scale. If there was added to this arrangement a simple scale of equal parts, so that the distance could be read by the method I have thus proposed, not only to an object of fixed height, as a man, but to any object of unknown height, it would, it appears to me, be of infinitely more use for range finding for military and other purposes.

PART IV.

On a contrivance proposed for altering the diaphragms of levelling telescopes to enable the Surveyor to utilize the principle of perspective in accordance with the remarks in Parts II. and III.

For new levelling telescopes the adaptation of the principle proposed in this paper can be effected in many ways, as it is only necessary to make the diaphragm in such a manner that within it a movable vertical space, either by platinum wire lines or fine points or otherwise, adjustable by the surveyor, can be attached thereto. In existing instruments also, opticians would no doubt be able to make fresh diaphragms on this principle to suit their own make of levelling instruments at all events. Considering, however, the large number of levelling telescopes there are scattered about the world, many of which it would be inconvenient and expensive to send to opticians for additions to their diaphragms, it appears to me that a simple contrivance is required, which can be inserted by the surveyor himself in the diaphragm of his instrument, and thereby he will be enabled to read distances, as explained in this paper.

To make such a contrivance of general use, it must be applicable to almost any make of instrument, and after giving the matter much consideration, I have suggested a contrivance to Messrs. Elliot Brothers, opticians, which can be inserted in any levelling telescope without any skilled workmanship, beyond boring a small hole in the telescope tube just behind the diaphragm, and which will answer the purpose required, viz. to give a vertical space adjustable by the surveyor in the diaphragm of the telescope without interfering with the existing cross hairs or spider lines which are required for reading the level height—and a scale of equal parts for use, as explained in Part III., will be attached thereto.

Messrs. Elliot Brothers, Strand, London, will be prepared, I believe, to supply this contrivance to surveyors, on

application, at a small cost, and it will be constructed in such a manner that the surveyor himself will be able to attach it to his levelling telescope, whatever the make of his level may be.

PART V.

On field books for levelling operations when reading distances, as explained in Part I.

THE old form of level field-book giving six columns for readings of the level heights on the staff, and their reduction for plotting purposes, viz. back, intermediate, and foresight, rise, fall, and reduced level columns, is unnecessarily long and tedious to be made up in any case, and when distances are read off the staff, and worked out afterwards by proportion, as explained in Part I. of this paper, where three columns are required for the distance readings and their reduction (see example, Part I.), it becomes still more so. I therefore recommend the system of keeping the readings of the level heights in one column, which is already done by many Engineers, though the system is not generally known and adopted;—the reduction of the levels is a much simpler process than from the old form of level book, and I have found it, after several years' use, no more liable to lead to mistakes in noting down the readings than the old form of book. I give an example of it here for those who are unacquainted with this simple system of level field-book—

Distance.	Level Readings.	Reduced Levels.	
—	—	101·00	Datum + first backsight, from which all level readings are to be deducted up to the next backsight.
0	1·00	100·00	Datum for plotting.
30	6·20	94·80	
100	9·50	91·50	
300	2·30	98·70	
Backsight	4·50	103·20	Not to be plotted. Last reduced level + new backsight to be used as new basis for calculation.
50	2·00	101·20	
100	7·50	95·70	
300	9·40	93·80	

It will be seen from this specimen that the readings, whether back, intermediate, or fore, are all entered in one column alongside of the distances. It is only necessary to draw a line under the last foresight every time the instrument is moved to take a backsight at that same place. As there are two opportunities given to the surveyor of drawing this line, namely, when taking the foresight, or the next backsight, after altering the position of his instrument, it is almost impossible for him to miss drawing this line at the right place; and if a surveyor were careless enough to do this, he is just as likely to make an equally fatal error in the old system of level field-book. The reduction of the levels for plotting is most simple, and will be understood by reference to the above specimen of field-book. To check the figures of the reduced levels, all that is necessary is to add all the backsights together, also all the foresights, and subtract one from the other, and their difference should agree with the difference of the first and last reduced level of the points surveyed. For instance, in the above field book there are:—

Two backsights	1·00 + 4·50 =	5·50
Two foresights	2·30 + 9·40 =	11·70
	Difference =	6·20

First reduced level at	0 =	100·00
Last „ „	at 300 =	93·80
	Difference =	6·20

The simplicity and neatness of this system is evident, and I think only requires to be more generally known to be used in place of the lengthy system of level field-book generally taught in works on surveying, and which, I believe, is more often adopted than the simple system above described.

UNIVERSITY OF ILLINOIS-URBANA
3 0112 112077000